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Stratigraphy and microfossil studies of the Sappington formation southwestern Montana

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STRATIGRAPHY AND MICROFOSSIL STUDIES
OF THE SAPPINGTON FORMATION,
SOUTHWESTERN MONTANA

by

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ABSTRACT

The Sappington formation of southwestern Montana is defined to include a lower black shale member, a middle member of silty shales and siltstone, and an upper black shale member, each having a restricted areal distribution. Stratigraphic data indicates that the Sappington can be separated on a physical basis from the underlying Devonian Three Forks formation.

Recent interpretations of megafaunal evidence suggest a Mississippian age for the Sappington, but some workers are of the opinion that both Devonian and Mississippian fossils occur in the Sappington middle member, thus disputing its suggested Mississippian age. In addition, Cyrtiopsis, a significant late upper Devonian brachiopod, is stated by Banta (1951) to be present in the Sappington middle member. Present evidence indicates that species of this genus are confined to the upper Three Forks shale and limestone sequence and that Banta's locality may be stratigraphically out of place.

The concept that the Sappington middle member interfingers with or grades laterally into other lithotopes is

discounted on the grounds that these relationships are not evident in field exposures near and at the lateral limits of the middle member and that no evidence is available for defining any lateral facies. Field relationships, progressive thinning and the invariable disappearance of the middle member suggest that it wedges out on top of the Three Forks formation in all directions.

Conodont studies demonstrate that the Sappington lower black shale member is not equivalent to either the Devonian black shale in the Flathead Range of northwestern Montana or the Little Chief Canyon member of the Lodgepole formation in central Montana. A comparison of fossil spore assemblages of the Sappington upper and lower black shales with fossil spores of the Little Chief Canyon member of central Montana strongly suggests that the upper black shale is equivalent to the Little Chief Canyon member.

INTRODUCTION

In an area of southwestern Montana that includes parts of Broadwater, Gallatin, Madison, Meagher and Jefferson Counties, geologists have identified a sequence of two black carbonaceous shales separated by a middle clastic unit that appears to be of restricted lateral extent. Stratigraphically these marine sedimentary rocks rest above the Three Forks formation, a unit known to be of Devonian age, and below the Lodgepole formation of Mississippian age. Because of this stratigraphic position and lack of good paleontologic control, the age of the Sappington beds is in dispute. They have been variously assigned: as the Sappington formation, Mississippian in age; as a local member and facies of the Devonian Three Forks formation; and as transitional beds on the Devonian-Mississippian boundary.

The relationship of the upper and lower black shale members in the Sappington interval with black shales of similar stratigraphic position in other areas of the Northern Rocky Mountain region is also questionable. Crickmay (1952) has presented faunal evidence that indicates apparent time equivalency between the Exshaw black shale of Alberta and the lower black shale member of the Sappington interval. There are, however, as yet no criteria for correlating either Sappington black shale member with the Little Chief Canyon member of the Lodgepole formation in central Montana or with the upper and lower black shale units of the Bakken formation, a basal Mississippian unit of the Williston Basin.

The purpose of this paper is to demonstrate that on physical evidence the Sappington beds can be separated as a formation from the underlying Three Forks formation and that a definite age determination for the Sappington formation is not possible at present because of conflicting and indefinite paleontological data. In the second part of this paper lithologic and micropaleontologic criteria will be presented for the correlation of the members within the Sappington formation.

Field and Laboratory Methods

In the summer of 1956, ten surface sections of the upper Three Forks-Sappington interval were measured in the area of its outcrop and six sections of the beds below the Mississippian Lodgepole formation were measured at localities outside the limits of the Sappington formation. The sections were measured by using the Brunton compass or Jacob staff, depending on the suitability of the instruments to circumstances of topography in each section. Six other sections were observed but soil cover and talus did not permit measurement of these sections. The county outline map

(Figure 1) shows the locations of all surface sections and well locations cited in this study. The measured sections were sampled at five-foot intervals. Additional samples were collected at significant lithologic breaks.

Megafossils were collected at four localities. Upper Three Forks fossils were not collected in place because they weather out of the upper green shale unit and are scattered at random over the surface of the green shale outcrops. All Sappington fossils were collected in place.

Surface and well samples were examined under a binocular microscope using a ten-power magnification. They were described according to the procedure outlined by Krynine (1948) for the megascopic description of sedimentary rocks. Colors used are those of the Rock Color Chart, National Research Council (1948). Thin sections were made and examined in cases where the rock sample was of doubtful mineral composition.

Previous Work

Peale (1893) divided the Three Forks-Sappington interval into lower shales, intermediate limestones, and upper shales. Raymond (1907) concluded that Sappington fossils represent a transition between Devonian and Mississippian forms. Schuchert (1910) believed that the presence of *Syringothyris carteri* and *Spirifer striatus* in the Sappington faunal assemblage indicated a distinct break in the faunal succession and he considered the Sappington as Mississippian in age. Haynes (1916) divided the Three Forks-Sappington interval into seven members, and he considered the entire interval as Devonian in age because of the presence of Productella, cf. P. arto striatus and Rhipidomella vanuxemi (?) in his members 1 and 2, or what is defined in this paper as the middle member.

At the Milligan Canyon section in T.2N., R.1W., Sec. 36, Berry (1943) found Syringothyris sixty feet below the base of the Lodgepole formation and proposed that the interval between the Syringothyris beds and the base of the Lodgepole formation be assigned to the Mississippian system. He identified this interval as the Sappington sandstone and established Milligan Canyon as the type locality. Sloss and Laird (1947) and Sloss and Moritz (1951) defined the Sappington as a facies variation and member of the Three Forks formation. Banta (1951) collected fossils from the Sappington and found that they included seven species with Devonian ranges, five species with Mississippian ranges and one species whose range crosses the systemic boundary.

Holland (1951) reports the occurrence of Syringothyris immediately above the lower black shale member at a section two miles north of Logan. Because of this occurrence he extended the limits of the Sappington formation to include the lower black shale member and reaffirmed it as Mississippian in age. Crickmay (1952) identifies Cyrtiopsis in the upper Three Forks green shales and overlying limestone. He emphasizes that *Cyrtiopsis* species are significant for the delineation of the top of the Devonian system in the Northern Rocky Mountain region. He also contends that the *Syringothyris* that occurs in the Sappington middle member is "one of the Rocky Mountain variants of the Kinderhook group of faunas". Nordquist (1953) recognizes the similarities in lithologic sequence and stratigraphic position between the Sappington formation and the Mississippian Bakken formation of the Williston Basin; however, he concludes that there is no evidence of lateral connection between the two formations. Morgridge (1954) believes the Sappington middle member represents an isolated body of lower Mississippian clastic sedimentation and that it grades laterally into carbonates of the lithic type.

Mann (1954) and Alexander (1955) in reporting on the geology of part of the Gravelly Range and the Whitehall areas respectively, agree with Sloss and Laird in that they consider the Sappington as a member of the Three Forks formation. McMannis (1955) argues that the Sappington formation can be separated from the Three Forks formation on lithologic and faunal criteria. He proposes that it be defined to include both black shales and the intervening sandy and silty beds. In a correlation chart, Norton (1956) shows the middle member wedging out to the southeast in the area between the Bridger Range and the vicinity of Livingston and the upper black shale member as a correlative of the Little Chief Canyon member of the Lodgepole formation.

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STRATIGRAPHY

Upper Three Forks Interval

In southwestern Montana the upper part of the Three Forks formation is characterized by a greenish grey to yellowish grey, fissile, siliceous shale that never exceeds 100 feet in thickness. This shale contains well preserved Devonian fossils that are listed by Haynes (1916), Holland (1952), and Crickmay (1952).

Wilson (1955) believes that this green shale unit can be extended into central Montana where it overlaps the Devonian Potlatch, Nisku and Duperow formations. This unit is accepted as a good stratigraphic marker and was used as the base for the surface sections measured by the writer.

At several localities, *e.g.* the Milligan Canyon type section, the Indian Creek section, T.7N., R.1E., Sec. 33, and the Hardscrabble Peak section, T.2N., R.7E., Sec. 5, the green shale unit is overlain by two to six feet of medium light grey to light olive grey, thin-bedded, fossiliferous, argillaceous limestone. Holland (1952) reports the highest occurrence of *Crytiopsis* (*Cyrtospirifer*), a significant late upper Devonian brachiopod, to be in this limestone.

Sappington Formation

Lower Black Shale Member

The lower black shale member is typically a dark grey to black, fissile, carbonaceous, conodont and fossil spore bearing shale. This sharp lithologic change from the underlying Three Forks shale and limestone interval is clearly noted in the Nixon Gulch section of the Horseshoe Hills, T.2N., R.3E., Sec. 14, and on Hardscrabble Peak in the Bridger Range (Figures 5 and 6). The position of this member in the Three Forks and Lewis and Clark Cavern areas is usually indicated by a dark purple color in the soil and by small pieces of black shale float.

In an apparently restricted though indefinitely known area of southwestern Montana, the lower black shale member intervenes between the limestone-shale sequence of the Three Forks formation and the Sappington middle member. This member has been found at nearly all localities from the Lewis and Clark Caverns on the west and the Bridger Range on the east. To the north the lower member has been traced to a locality in T.3N., R.2E., Sec. 30. Beyond this locality to the north and northeast, in the Indian Creek section and in Sixteen Mile Canyon, T.5N., R.5E., Sec. 12, the Three Forks-Sappington contact is covered and it is not known whether the lower black shale is present or not. To the south, the lower black shale member has not been reported outside of the Three Forks quadrangle. Mann (1954) does not report the lower black shale in the Gravelly Range and it is not found in a well exposed upper Devonian-lower Mississippian section on the north flank of Sheep Mountain in the Centennial Range. The lower black shale varies in thickness between six inches at the Logan section in 2E., Sec. 25, and nineteen feet in the northern part of the Bridger Range.

Limonitic Shale Bed

At several localities in and to the west of the Three Forks quadrangle the lower black shale member is overlain by up to ten feet of varicolored, thin-bedded, limonitic shale. The position of this shale is indicated by conspicuous red, purple and buff colors.

The limonitic shale was observed at several localities in the Three Forks quadrangle, at Lewis and Clark Caverns, and at the Copper City section in T.2N., R.3W., Sec. 21. However, it is not present at the Grizzly Gulch section in T.9N., R.4E., Sec. 10, at the Camp Creek section three miles east of Melrose, nor to the east of the Three Forks quadrangle.

At most localities the contact between the lower black shale member and the limonitic shale is gradational and difficult to separate into individual and distinct rock units. It then seems best, from a consideration of this gradational contact and the small restricted area of the limonitic shale, to recognize it as a bed within the lower black shale member.

Middle Member

The 40- to 110-foot interval of silty shales and siltstone, here identified as the middle member, is a body of restricted areal distribution. Morgridge (1954) regards this interval as an isolated body of lower Mississippian clastic sedimentation. Sloss (written communication, 1957) is also of the opinion that "the Sappington and related sandy units must represent patterns of limited areal distribution".

The isopachous map (Figure 2) illustrates a nearly symmetrical configuration of thickness in this middle member. It also appears from the map that the middle member is restricted to a definite area in southwestern Montana.

Subunits

While tracing the middle member in the field, it was found that it could be divided into three persistent subunits on the basis of bedding and other structural characteristics, weathering nature, topographic expression and minor but distinctive vertical changes in lithology. At nearly all localities one, or a combination, of these features was used to differentiate the middle member into lower, middle, and upper subunits.

In general, the lower subunit embraces a 15- to 31-

foot interval of thin to thick-bedded silty calcareous shale and siltstone that, locally, includes up to four feet of argillaceous limestone at its base. Vertical joints filled with calcite were observed to cut the lower subunit at the Milligan Canyon section, at Nixon Gulch, and on Hardscrabble Peak. At Nixon Gulch, Hardscrabble Peak and several localities in the Three Forks quadrangle, the base of the lower subunit is characterized by a nodular zone.

Megafossils are present near the base and top of the lower subunit. At the Hardscrabble Peak section several varieties of brachiopods and one pelecypod were found from the base to a level ten to fifteen feet above the base. Fossils also occur at Milligan Canyon. A collection that included *Syringothyris*, *Spirifer* (?), *Rhipidomella* and *Dictyoclostus* (?) was made a few inches below the contact between the middle and lower subunits. Banta (1951), Holland (1952), and Morgridge (1954) report collections from a bed a few feet above the base of the lower subunit at the Logan section, but apparently did not find fossils at the top of the subunit. The lower part of the lower subunit at the Copper City section yielded *Syringothyris*, *Dictyoclostus* (?) and several other brachiopods, but fossils were not found higher at this locality. Therefore, with the exception of the Milligan Canyon type locality, Sappington megafossils appear to be confined to the lower part of the lower subunit. Figure 5 illustrates the bedding characters and the upper and lower boundaries of the lower subunit.

The middle subunit is defined by a minor but distinct vertical change to a grey calcareous shale with very thin (1/16 inch to 1/8 inch) intercalations of silt. Near the top the subunit becomes more silty but retains the shaly-bedded character. Because of its shaly composition, the subunit weathers easily and is generally covered. Its presence is indicated by the contrast between the buff to yellow weathering colors of the lower subunit and the light grey color of the middle subunit. Its thickness ranges from 18 to 29 feet. Figures 5 and 8 illustrate the lower and upper boundaries of the middle subunit.

The upper subunit is made up of 24 to 42 feet of yellowish grey to brownish orange, flaggy to massive, well indurated, calcareous siltstone. It is generally the most conspicuous of the subunits (Figure 5). At T.1S., R.1W., Sec. 9, the upper subunit contains crossed laminations. The laminations average 4 mm. wide.

Thin sections reveal that the upper subunit is composed predominently of angular quartz grains in the silt size range (Wentworth grade scale). The quartz grains are cemented by calcite that is frequently coated with limonite and argillaceous material. Muscovite and rutile occur in very minor amounts.[1]

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[1]As this paper was in final preparation, Gutschick and Perry (1957) report on sedimentary features present in

Upper Black Shale Member

The upper black shale is typically a dark grey to black, fissile to very thin-bedded, sandy, carbonaceous shale containing conodonts and fossil spores. At Hardscrabble Peak in the Bridger Range the upper black shale is overlain by a six- to eight-inch bed of silt and very fine grained quartz sand. Stringers of black shale were observed to be intercalated between the silty and sandy beds.

Within the Three Forks quadrangle and to the north, south and west of this quadrangle, the upper black shale is missing and the Lodgepole formation rests directly upon the Sappington middle member. However, in a restricted area to the east and northeast of the Three Forks quadrangle, two to four-and-a-half feet of the upper black shale member intervenes between the top of the Sappington middle member and the base of the Lodgepole formation. The upper black shale is present in sections at Logan, Nixon Gulch in the Horseshoe Hills, Hardscrabble Peak in the Bridger Range,

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the Sappington middle member. Several of these features, namely nodules, burrows, ripple marks and crossbedding, assist in recognizing subunits within the middle member. The nodules that persist at the base of the lower subunit are identified by Gutschick and Perry as spongiostromatid algae. Burrows are common near the top of the middle subunit and features resembling ripple marks occur at the base of the upper subunit at Lewis and Clark Caverns. Crossbedding similar to the type illustrated by Gutschick and Perry in channel siltstones at Antelope Creek and Red Hill is also present in siltstones of the upper subunit at T.1S. R.1W., Sec. 9.

and Sixteen Mile Canyon. It is also present in the California Co., Crowley No. 1 well in T.5N., R.7E., Sec. 35. Figure 7 shows a view of the upper black shale member at Hardscrabble Peak.

It has been concluded by Holland (1952), Morgridge (1954), and Norton (1956), that an unconformity exists between the top of the middle member and the base of the Lodgepole formation. Holland (1952) seems to regard the presence of the upper black shale in the Bridger Range and its absence at Milligan Canyon as evidence for an unconformity. Morgridge (1954) has detected relief on the surface of the middle member to the extent of two feet in fifteen lateral feet. He also considers the presence of phosphate nodules in a sandy lens of the upper black shale and a slight angular surface to the upper black shale as evidence to support his conclusion that the contact is disconformable. Norton (1956) considers the presence of glauconite in material at the Sappington middle member-Lodgepole contact at Lewis and Clark Caverns as evidence of unconformity.

Morgridge (1954) does not attach any regional significance to this disconformity. The writer concurs with this conclusion because it has not been demonstrated that the Sappington-Lodgepole contact marks a distinct break in the faunal succession.

SAPPINGTON AGE PROBLEM

Schuchert (1910), Berry (1943), Holland (1952), and Morgridge (1954), consider the Sappington as Mississippian in age because of the occurrence, in the lower part of the middle member, of a fauna characterized by Syringothyris and species bearing affinities to species found in the Louisiana limestone (Mississippian) of Missouri. The Sappington Syringothyris species has been identified as S. hannibalensis, a species regarded by Wellar et al. (1948) as a Mississippian guide fossil with an earliest occurrence above the base of the Mississippian system. Collections made by Haynes (1916), Berry (1943), Banta (1951), Holland (1952), Morgridge (1954), McMannis (1955), and by the present writer, indicate that the Syringothyris zone is confined to the lower subunit of the middle member.

Collections by Banta (1951), Holland (1952), and Morgridge (1954), reveal that the Sappington assemblage includes Spirifer marionensis, Amboecelia minuta, and a Rhipidomella, cf. R. missouriensis. In addition, Laudon (1955) states that the crinoids from the Sappington "represent stages of evolution that are definitely progressive from known Devonian genera".

Some workers, however, point out that an intermingling of Mississippian and Devonian fossils occurs in the Sappington middle member. Haynes (1916) and Banta (1951) have identified several fossils in the Sappington assemblage with apparent Devonian affinities. Sloss (written communication, 1957) maintains that an "interbedding of at least two faunules" is evident at the Milligan Canyon type locality. Therefore, it is evident, if the above data is valid, that a Mississippian age for the Sappington could be questioned on the grounds that there is an intermingling of Devonian forms with characteristic Mississippian fossils in the Sappington middle member. Until more thorough investigations are conducted, it is apparent that the precise age of the Sappington will remain uncertain.

Extremely important tothe solution of the age of the Sappington is the determination of the highest occurrence of Cyrtiopsis in the Sappington-Three Forks interval. Crickmay (1951) has shown that this brachiopod is a significant fossil for defining the top of the Devonian system in the Northern Rocky Mountain region. It has been observed by Haynes (1916), Berry (1943), Holland (1952), Morgridge (1954), and in this study, that Cyrtiopsis species are restricted to the upper Three Forks shale and limestone interval that immediately underlies the lower black shale member of the Sappington.

However, Banta (1951) reports that Cyrtiopsis species occur in "yellow shales" at the base of the Sappington at the Logan section and a section east of Trident. It is not clear whether the "yellow shales" mentioned by Banta belong to the basal part of the Sappington middle member or are a part of the upper Three Forks shale and limestone sequence. At the Logan section, six inches of the Sappington lower black shale separates the *Cyrtiopsis* bearing limestone-shale sequence of the upper Three Forks interval from the Sappington middle member. Moreover, shale beds of both the upper Three Forks and Sappington middle member weather to buff and yellowish colors. Apparently Banta was unaware of the presence of the lower black shale member at the Logan section. If so, it appears likely that he may have collected his *Cyrtiopsis* species from the Three Forks "yellow shales" and erroneously assigned them to the basal part of the Sappington.

There is also disagreement among workers over the age of Sappington conodonts. Morgridge (1954) regards conodonts from the lower black shale member as closer to Mississippian in age than Devonian. McMannis (1955) suggests that conodonts from both Sappington black shales have more affinity to Devonian types. These conflicting views indicate that further studies of the age significance of Sappington conodonts should be made.

CORRELATION CRITERIA FOR SAPPINGTON MEMBERS

Physical

On a regional scale, a correlation of Sappington members requires a clarification of the lateral relationships of the middle member. Sloss (written communication, 1957) believes that the Sappington (middle member) represents a sand body that lies on the margin of the late Devonian-early Mississippian depositional basin and that the sands "intertongue and intergrade with shales and limestones as the axis of the basin is approached". Morgridge (1954) concludes that the middle member grades laterally into "carbonates of the lithic type".

It is the considered opinion of the writer that the Sappington middle member does not grade laterally into or interfinger with shales and limestones. No evidence was seen at any exposure to indicate that the Sappington middle member interfingered or graded into any other lithotope, laterally or vertically. Furthermore, if the Sappington middle member grades laterally into or interfingers with shales and limestones, then the concept of facies demands that lateral equivalents of the middle member be present. There is no fossil or lithologic evidence for delineating beds outside the limits of the Sappington middle member as facies of this member. In view of these conclusions, the

Sappington middle member is interpreted as pinching out on top of the Three Forks formation in all directions instead of intertongueing or intergrading with other deposits. (Figure 3).

From the standpoint of local and regional considerations, the Sappington middle member appears to represent one of at least two and possibly three areally segregated and geographically separated rock units that occupy similar positions in the stratigraphic column and that have not been shown to have lateral equivalents. Another rock unit is the medial calcareous sandstone of the Bakken formation of the Williston Basin. Nordquist (1954) in his subsurface correlations shows this unit to grade southwards into a fine grained dolomite that, in turn, wedges out to the south. He did not refer to any lateral equivalents of the Bakken medial sandstone unit present south of the formation's zero isopach line.

There is also indication that a calcareous siltstone unit underlying the Lodgepole formation in extreme southwestern Montana may represent a third example of restricted clastic deposition at the Devonian-Mississippian boundary. Thirty-five feet of this unit is present on the north flank of Sheep Mountain in the Centennial Range (Figure 10). Present field data show that this unit is not continuous with the Sappington middle member and that its lateral extent to the north and east appears to be confined principally to extreme southwestern Montana.

There are as yet no satisfactory criteria for a physical correlation of Sappington black shale members with black shale units of similar stratigraphic positions in other areas of the Northern Rocky Mountain region. Norton (1956) has made the upper black shale member of the Sappington the equivalent of the Little Chief Canyon member of the Lodgepole formation in central Montana because of their similarities in stratigraphic position. On purely physical evidence, the lower black shale member of the Sappington could just as well be equivalent to the Little Chief Canyon member. Other than the similarities of stratigraphic positions, there are also no physical criteria for relating the Sappington black shale members with the upper and lower black shale units of the Bakken formation. Similarly, a correlation of either Sappington black shale member with the Exshaw formation cannot be established on purely physical grounds. It is therefore evident that other criteria are needed before a regional correlation of the Sappington black shale members can be accomplished.

Microfossils

Introduction

In an attempt to better understand the regional relationships of the Sappington black shale members, conodont and fossil spores were extracted from the upper and lower black shale members and were compared with the conodont and spore assemblages of the basal Mississippian black shale (Little Chief Canyon member of the Lodgepole formation) that is exposed along Crystal Lake Road on the northwest flank of the Big Snowy Mountains of central Montana (Figure 11). In addition, the conodonts extracted from the Sappington black shale members were compared with published illustrations and descriptions of Devonian and lower Mississippian black shale conodonts of Montana.

Laboratory Procedure

Conodonts were extracted by boiling the black siliceous shales in a saturated solution of sodium metaphosphate. This softened the shales and allowed removal of the specimens.

Spores were isolated by first digesting the silica in the shales in hydroflouric acid. Next the samples were washed free of acid and treated with Schultz solution (three parts nitric acid to one part saturated solution of potassium chlorate) for the oxidation of carbonaceous matter. The samples were then washed free of Schultz solution and the humic material was dispersed in a 7% solution of potassium hydroxide. The resulting residues were thoroughly washed and centrifuged to collect the spores and other preserved vegetable matter.

Some of the residues containing spores were stored in 100% ethyl alcohol and stained with .5% safranine to facilitate observation under the microscope. They were permanently mounted in Technicon, a standardized histological reagent. Other spore residues were stored in water to facilitate handling under the microscope.

Conodonts

Collections of Sappington conodonts reveal that at least three assemblages are present in the Sappington interval. One assemblage, collected at the Hardscrabble Peak section, occurs in the top several inches of the lower black shale member. Another assemblage collected at the Logan section is found at the top of the middle member where it is in contact with the upper black shale member. The third assemblage is found in the upper black shale member at the Logan section and at Hardscrabble Peak in the Bridger Range.

The following species were identified from the conodont assemblage of the lower black shale member at Hardscrabble Peak:

Hindeodella, *cf*. *H*. *aculeata* Huddle
Hindeodella spp.
Lonchodus simplex (?) Pander
Lonchodus sp.
Prioniodina sp.
Spathognathodus spp.

Morgridge (1954) identified the following species from the lower black shale at the same locality:

Bryantodus crassidens Ulrich and Bassler
Bryantodus scitulus Branson and Mehl
Hindeodella deflecta Hubbard
Hindeodella elongata Huddle
Hindeodella macelenta Hibbard
Hindeodella modesta Stauffer
Ozarkodina regularis Branson and Mehl
Spathognathodus peculiaris E. R. Branson

A comparison of the Sappington lower black shale assemblage with the conodont assemblage described by Cooper (1945) from a Devonian black shale unit in the Flathead Range of northwestern Montana reveals the following data:

1. A common genus in both assemblages is *Hindeodella*. However, only one species, *Hindeodella aculeata*, is present in both assemblages.

2. Of the seven genera represented in the Sappington lower black shale assemblage, only three, *Hindeodella*, *Bryantodus*, and *Spathognathodus*, are found in the Devonian black shale unit in the Flathead Range.

The comparison of these data indicates that these two shale units cannot be considered as equivalents.

Cooper and Sloss (1943) recorded a conodont assemblage from a black shale that underlies the Lodgepole formation at widely scattered localities in Montana and Alberta.

They considered this black shale as the basal Mississippian unit because of the "Kinderhook age of the conodont fauna". Knechtel, Smedley and Ross (1954) identify this black shale as the Little Chief Canyon member of the Lodgepole formation. A comparison of Sappington lower black shale assemblage with the Little Chief Canyon member yields the following results:

1. The Sappington lower black shale has a meager representation of the conodont species identified from the Little Chief Canyon member by Cooper and Sloss. Of the seventeen species listed by Morgridge and in this study from the Sappington lower black shale only Hindeodella elongata and Ozarkodina regularis are present among fifty-four species listed from the Little Chief Canyon member.

2. Although six of seven genera present in the Sappington lower black shale occur in the Little Chief Canyon member, there are fourteen genera in the Little Chief Canyon member that do not occur in the Sappington lower black shale. Therefore, on present evidence, there is little basis for considering these two black shale units as equivalents.

At the Logan section, a conodont assemblage occurs at the top of the Sappington middle member where it is in contact with the upper black shale member. This assemblage is distinct in that 50% or more of the conodonts are species of Siphonognathus and Polygnathus. Furthermore, the top of the middle member is the only level in this member that contains conodonts. Therefore, these conodonts are interpreted as belonging to a distinct assemblage rather than to the conodont assemblage of the overlying upper black shale member. The following species were identified from this assemblage:

Ligonodina, cf. platys Cooper
Polygnathus sp.
Siphonognathus quadruplicata Branson and Mehl
Siphonognathus sp.
Spathognathodus sp.

The upper black shale member yielded only a small number of conodonts. The following species were collected at the Logan section and at Hardscrabble Peak, Bridger Range:

Bryantodus sp.
Ligonodina platys Cooper
Ligonodina, cf. tenera Cooper
Ligonodina sp.
Siphonognathus (?) sp.

It is believed that a representative conodont assemblage from the upper black shale member was not obtained in these samples because specimens are not found to be concentrated at any certain layer but are lightly distributed throughout the upper black shale. It is concluded that a more representative sample must be collected before a satisfactory comparison can be made with other black shale assemblages.

Fossil Spores

Examinations of fossil spore assemblages from both Sappington black shale members reveal that the lower black shale assemblage is distinct from the upper black shale assemblage. Schopf (written communication, 1957) has examined the spores of both black shales and concludes that "there are probably spores of land plants as well as several types of *Tasmanites* present". Moreover, there are striking differences in the abundance and types of *Tasmanites* and land plant spores present in the black shale members.

The spore assemblage of the lower black shale at Hardscrabble Peak, Bridger Range, is dominated by species of *Tasmanites*. It is estimated that 85% of the assemblage is made up of species of this genus. Schopf (written communication, 1957) is of the opinion that two or possibly three species of *Tasmanites* are represented and that certain thin-coated forms of *Tasmanites* "must be distinct". One species ranges in size from 110 to 260 microns (long diameter), possesses a thick, slightly punctate spore coat, and, on the larger forms, contains a circular split in the spore coat that was probably caused by compression (Figure 14). Other species are distinguished by a thin, often folded, spore coat and ranges in size from 100 to 230 microns (Figures 15 and 17). Another form that ranges in size from 80 to 144 microns shows a conspicuous punctate-reticulate ornamentation (Figure 16). Most of these species have been altered by compression into disc and oval shapes. They do not possess the trilete and monolete rays that are characteristic of land plant spores.

Schopf (written communication, 1957) points out that the land plant spores in the Sappington black shales are much smaller in size than the Tasmanites specimens. The smallest spore in the lower black shale assemblage is represented by a disc-shaped form with a punctate spore coat and an average diameter of around 32 microns. However, it is questionable whether they are true land plant spores since neither trilete nor monolete rays were observed to be present on these forms.

The fossil spore assemblage of the upper black shale member at Sixteen Mile Canyon is composed predominently of several varieties of spores that do not occur in the lower black shale assemblage. Most of these species have not been assigned to genera pending further studies. The following descriptions of the upper black shale assemblage are patterned after the descriptive procedure used by Schopf (1944) for Paleozoic spore genera:

1. Genus - unknown.
   Symmetry - radial.
   Size - 34 to 50 microns.
   Ornamentation - spinose.
   Haptotypic features - sutures not visible.

2. Genus - Punctati-sporites.
   Shape - disc-shaped.
   Size - 48 microns (long diameter).
   Ornamentation - spore coat thin and finely

punctate.
Haptotypic features - trilete rays observed; they do not appear to extend completely to edge of spore coat.

3. Genus - unknown.
Shape - spherical (?) body with two bladders that extend outwards and possibly downwards from the main body.
Size - approximately 80 microns from bladder tip to bladder tip.
Haptotypic features - no sutures observed.

4. Genus - unknown.
Shape - spherical (?).
Size - 20 microns (long diameter).
Ornamentation - numerous processes and projections extending from a levigate coat.
Haptotypic features - sutures not visible.

5. Genus - unknown.
Shape - disc-shaped.
Size - 40 microns (long diameter).
Ornamentation - reticulate with setaceous-like projections. A fold occurs just inside edge of spore coat and parallels the circumference of the specimen.
Haptotypic features - no sutures observed.

6. Genus - unknown.
Shape - spherical.
Size - 30 microns.
Ornamentation - coarsely and irregularly reticulate with a finely punctate body wall.
Haptotypic features - no sutures observed.

7. Genus - unknown.
Shape - disc-shaped.
Size - 34 microns.
Ornamentation - spore coat punctate with a few rounded folds.
Haptotypic features - no sutures observed.

8. Genus - <u>Tasmanites</u>.
Symmetry - unicenter.
Shape - disc-shaped.
Size - 120 microns (long diameter).
Ornamentation - coat reticulate.
Haptotypic features - no trilete rays.

9. Genus - unknown.
   Symmetry - radial.
   Shape - disc-shaped.
   Size - 16 microns (long diameter).
   Ornamentation - difficult to determine because of small size.
   Haptotypic features - sutures not observed.

In comparing the fossil spore assemblages of the upper and lower black shale members, two striking differences are evident. Although Tasmanites is present in both assemblages, it is the dominant genus in the lower black shale, but is found only occasionally in the upper black shale. None of the eight remaining species of the upper black shale assemblage occur in the lower black shale assemblage, with the possible exception of two forms, the spherical (?) body with two bladder processes, and Punctati-sporites spp. It is therefore believed that these differences are significant and that they will be of use in the regional correlation of Sappington black shale members.

To test the usefulness of spores in the regional correlation of Sappington black shale members, the respective assemblages of the lower and upper black shales were compared with the fossil spore assemblage of the Little Chief Canyon member of the Lodgepole formation that is exposed along Crystal Lake Road in the Big Snowy Mountains of central Montana. A comparison of the Sappington lower black shale assemblage with the Little Chief Canyon member assemblage results in these conclusions:

1. Tasmanites occurs in both assemblages, but only

one species is recognizable in the Little Chief Canyon member, whereas two or possibly three species are found in the Sappington lower black shale. In relative abundance Tasmanites is the dominant element in the Sappington lower black shale assemblage, but it is found only occasionally in the Little Chief Canyon member.

2. The Little Chief Canyon member is characterized by a variety of small spores with probable land plant affinities. In the Sappington lower black shale, there are only two forms, Punctati-sporites (?) and spherical body with two bladder processes, that can be regarded as land plant spores. These two shales, therefore, have no relationship because of the differences in their spore composition.

A comparison of the spore assemblage of the Sappington upper black shale with the Little Chief Canyon member assemblage indicates that these shales are closely related in spore composition. Tasmanites, Punctati-sporites, and species nos. 1, 3, 5, 6 and 7 of the nine forms indicated from the upper black shale, are present in the Little Chief Canyon member. On the basis of a common occurrence of spore species in these black shales and their identical stratigraphic positions, the upper black shale member of the Sappington formation is regarded as the equivalent of the Little Chief Canyon member of the Lodgepole formation as present in the Big Snowy Mountains of central Montana.

CONCLUSIONS

1. In southwestern Montana the Sappington formation overlies the Devonian Three Forks formation and underlies the Mississippian Lodgepole formation. It is composed of two black shale members separated by a middle member of silty shales and siltstone.

2. The lower black shale member underlies the middle member at most localities throughout the east-west extent of the middle member; however, it is apparently restricted in its distribution to the north and south of the area between Lewis and Clark Caverns and the Bridger Range.

3. As previously proposed by Morgridge (1954) and Sloss (written communication, 1957), the Sappington middle member represents a confined body of clastic sedimentation as evidenced by its thinning and eventual disappearance in all directions from its area of maximum thickness northwest of the village of Three Forks.

4. The upper black shale member is also limited in its areal extent as it overlies the middle member only in approximately the eastern one-half of the area occupied by the middle member.

5. Silty shales and siltstones of the Sappington middle member are separated from Three Forks shales and limestones by the lower black shale member. At several

localities in and to the north, south and west of the Three Forks quadrangle, a limonitic shale bed intervenes between the lower black shale and middle members of the Sappington, and its base can be considered to mark the contact between the Sappington and Three Forks where the lower black shale member is missing. The middle member is further distinguishable from the Three Forks by the presence of <u>Syringothyris</u>, a characteristic Mississippian brachiopod.

6. Minor but distinctive vertical changes in lithology and the lateral continuity of these vertical changes are physical criteria for the correlation of Sappington members. The black shale members represent distinct lithotopes that are readily traced between exposures. The middle member can be divided into three persistent subunits that display within themselves the same vertical variations in lithology, bedding and weathering characteristics and fossil content.

7. The belief that the Sappington middle member interfingers with and grades laterally into limestones and shales is discounted on the grounds that these relationships are not evident in exposures. Sections near or outside the pinch-out edge of the middle member do not reveal interfingering between Sappington beds and other deposits. Moreover, there is no indication of lateral facies change in the middle member.

8. Conflicting data on the significance of Sapping-

ton megafossils and the highest occurrence of Cyrtiopsis in the Sappington-Three Forks interval have resulted in an indefinite age assignment for the Sappington. It is unlikely, however, that Cyrtiopsis occurs higher than the upper Three Forks shale and limestone sequence.

9. A study of conodonts from the Sappington black shale members indicates that the lower black shale assemblage is not comparable to the conodont assemblage of the Devonian black shale in the Flathead Range, northwestern Montana, or to the assemblage of the Little Chief Canyon member of the Lodgepole formation of central Montana. Therefore, they are not regarded as equivalents of the Sappington lower black shale member. A complete study of conodont species from the upper black shale member is needed before they can be used in efforts to correlate the upper black shale with other shales at the Mississippian-Devonian boundary in the Northern Rocky Mountain region.

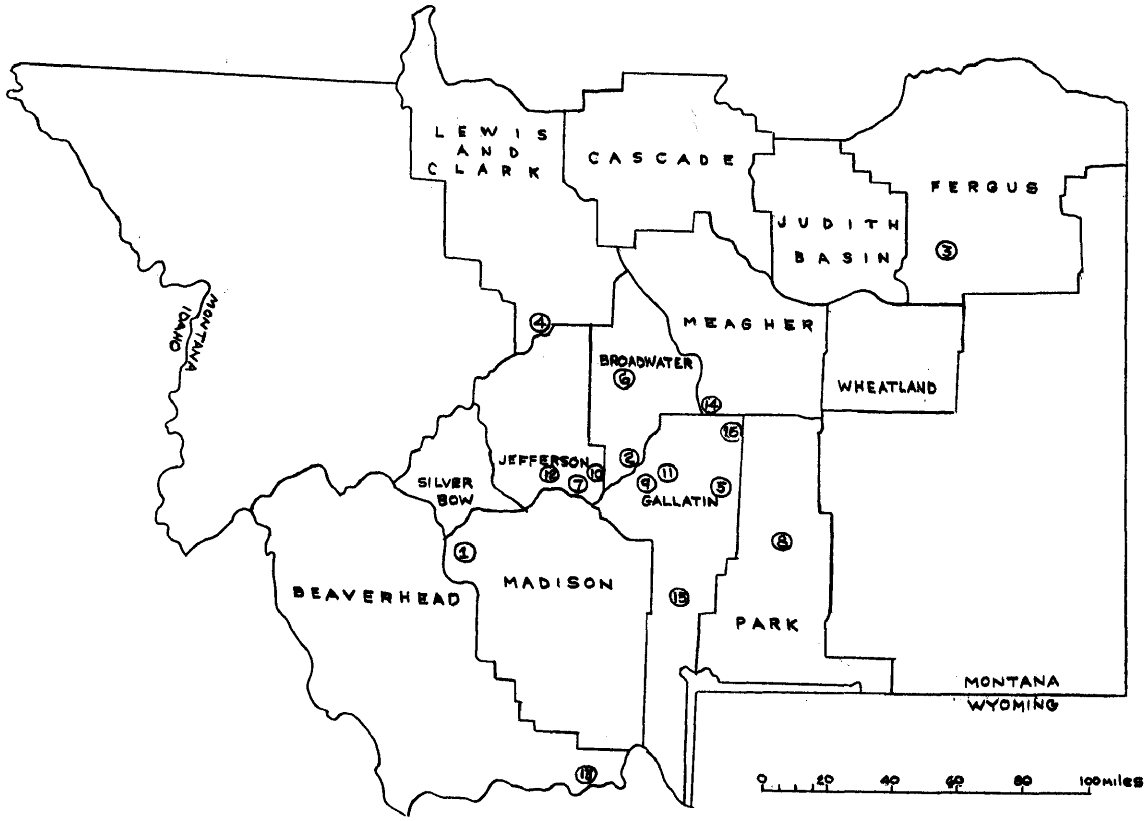
10. The differences in fossil spore assemblages between Sappington black shale members are distinct. Two or possibly three species of Tasmanites dominate the lower black shale assemblage but land plant spores are found only occasionally. In contrast, the upper black shale is characterized by an assemblage of at least eight varieties of land plant spores and Tasmanites occurs only as one species.

Only three spore species found in the lower black shale have been identified in the spore assemblage of the

Little Chief Canyon member of the Lodgepole formation in central Montana, whereas seven of nine spores from the upper black shale are definitely referable to species from the Little Chief Canyon member. This strongly suggests that the Sappington upper black shale is the correlative of the Little Chief Canyon member.

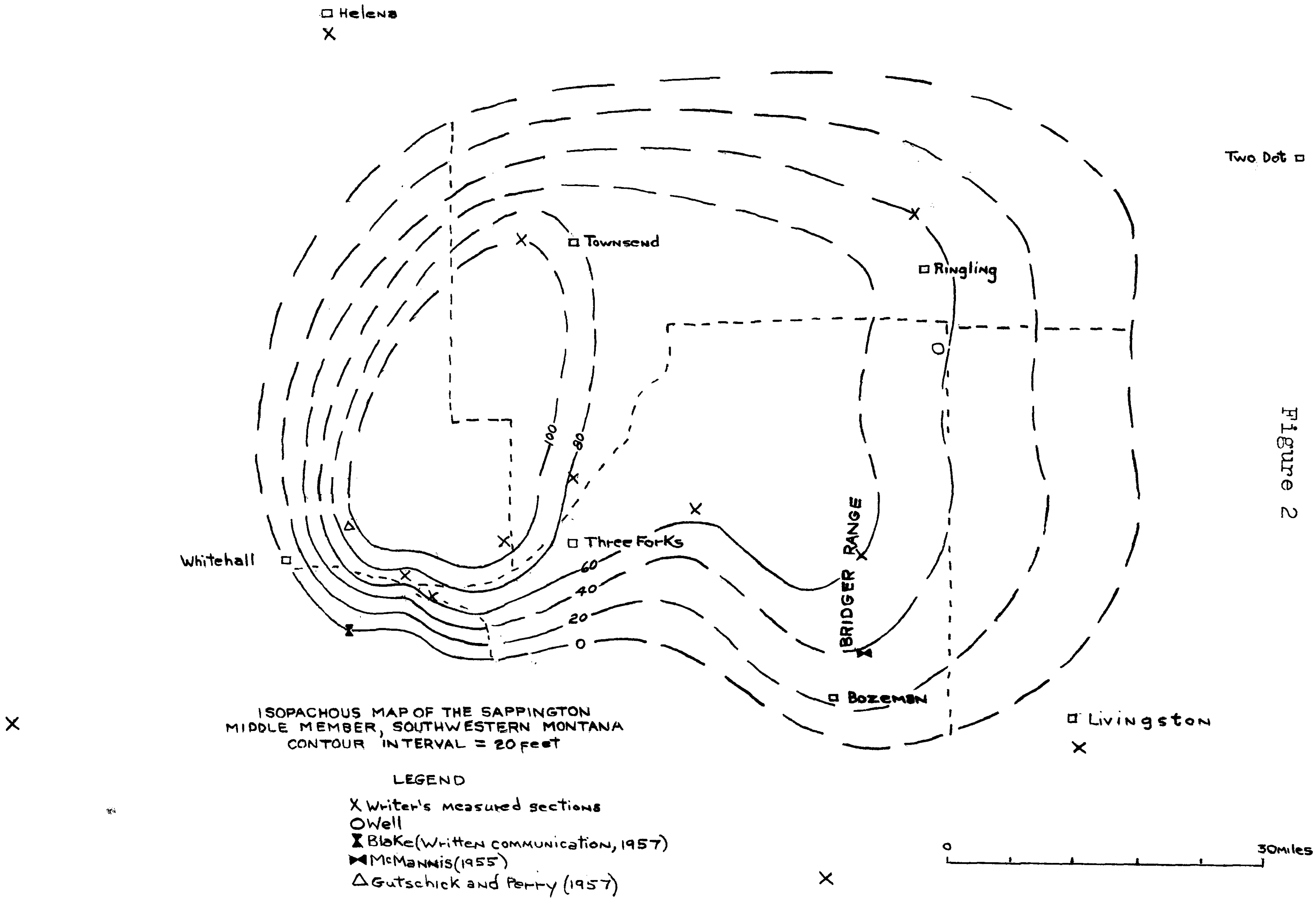
ILLUSTRATIONS AND PLATES

Figure 1



County outline map of Southwestern Montana showing the locations of sections referred to in the text.

1. Camp Creek section.
2. Copper City section.
3. Crystal Lake Road section, Big Snowy Mountains.
4. Grizzly Gulch section.
5. Hardscrabble Peak section, Bridger Range.
6. Indian Creek section.
7. Lewis and Clark Caverns section.
8. Livingston Peak section.
9. Logan section.
10. Milligan Canyon section.
11. Nixon Gulch section, Horseshoe Hills.
12. Red Hill section.
13. Sheep Mountain section, Centennial Range.
14. Sixteen Mile Canyon section.
15. Storm Castle Mountain section.
16. California Co., Crowley No. 1.

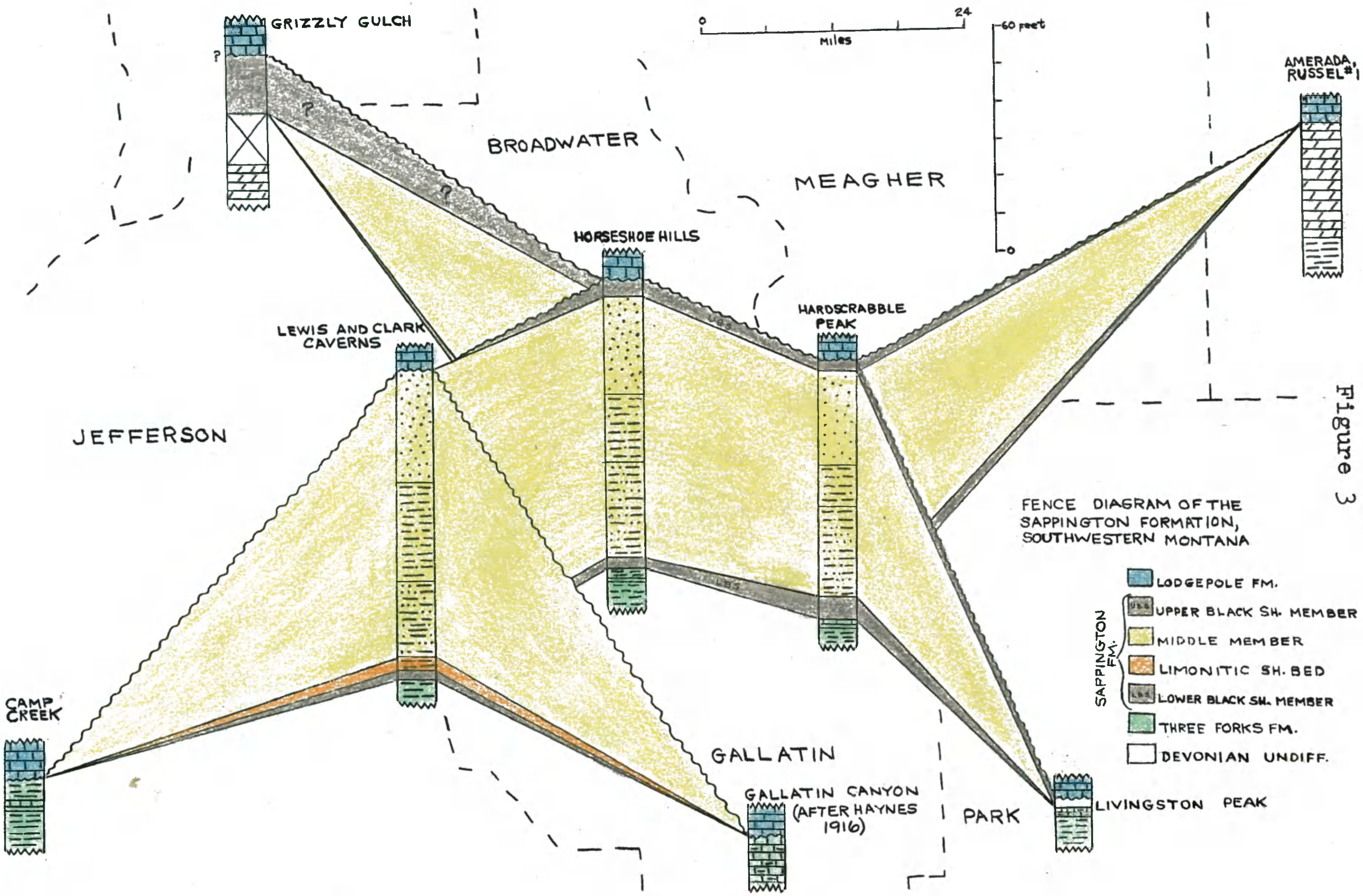


ISOPACHOUS MAP OF THE SAPPINGTON MIDDLE MEMBER, SOUTHWESTERN MONTANA
CONTOUR INTERVAL = 20 feet

LEGEND

X Writer's measured sections
O Well
Blake (Written communication, 1957)
McMannis (1955)
△ Gutschick and Perry (1957)

Figure 2



GRIZZLY GULCH
?
BROADWATER
MEAGHER
0
24
Miles
60 feet
0
AMERADA, RUSSEL #1
HORSESHOE HILLS
HARDSCRABBLE PEAK
LEWIS AND CLARK CAVERNS
JEFFERSON
FENCE DIAGRAM OF THE SAPPINGTON FORMATION, SOUTHWESTERN MONTANA
LODGEPOLE FM.
SAPPINGTON FM.
UPPER BLACK SH. MEMBER
MIDDLE MEMBER
LIMONITIC SH. BED
LOWER BLACK SH. MEMBER
THREE FORKS FM.
DEVONIAN UNDIFF.
CAMP CREEK
GALLATIN
GALLATIN CANYON (AFTER HAYNES 1916)
PARK
LIVINGSTON PEAK

Figure 3

Figure 4

Columnar Section, Sappington Fm., Hardscrabble Peak, Bridger Range

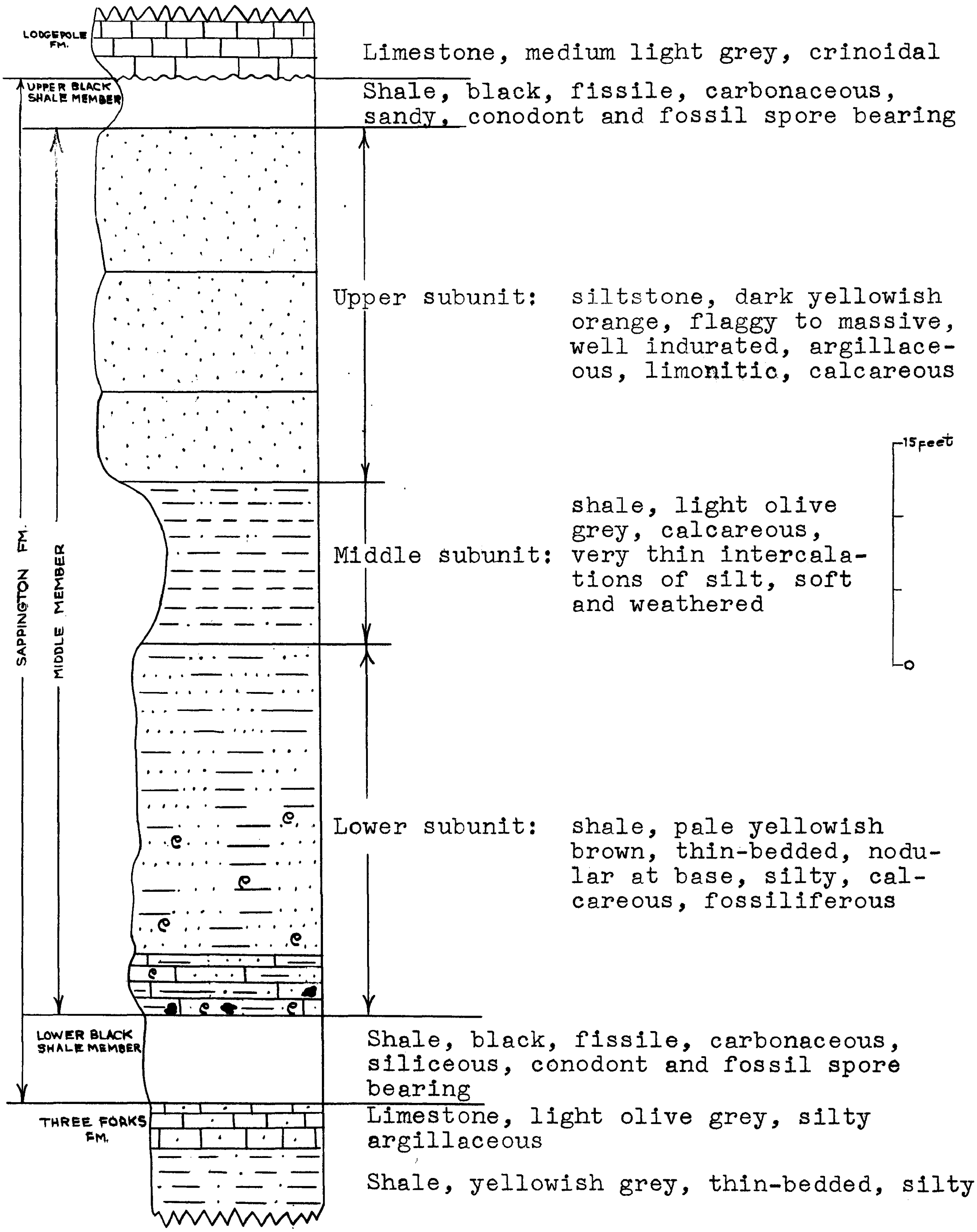
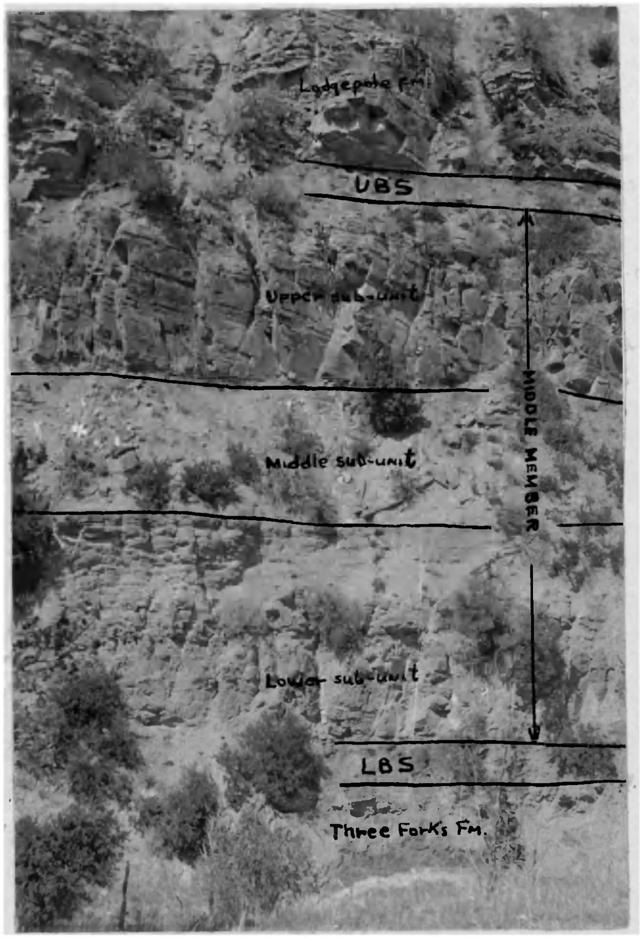
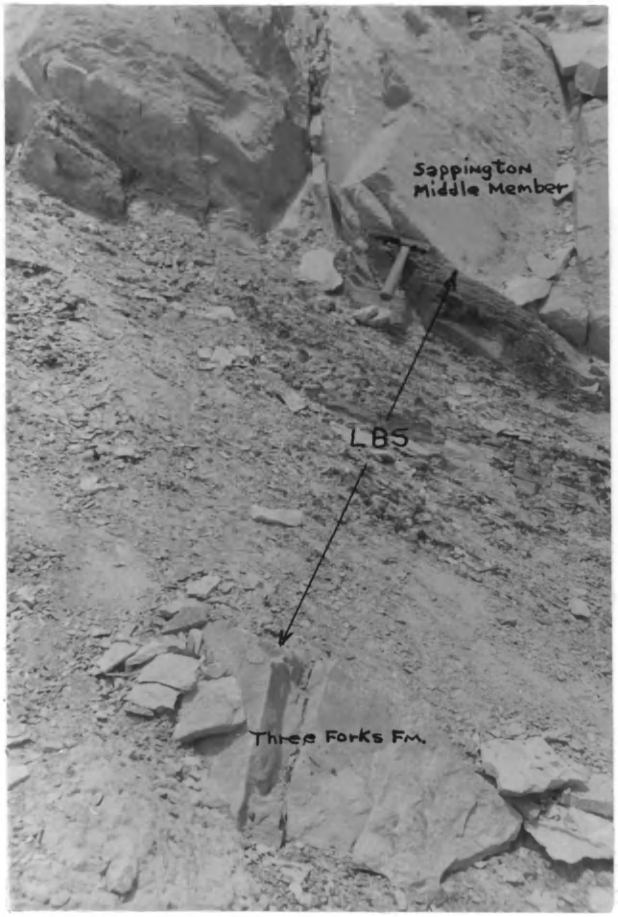


Figure 5



View of the Sappington formation showing its contact with the overlying Lodgepole formation and the underlying Three Forks shales and limestones. Note the vertical and lateral changes in bedding of the lower subunit, soft weathering nature of the middle subunit and the massive resistant siltstone beds of the upper subunit. LBS and UBS designate lower black shale and upper black shale respectively. Nixon Gulch section in the Horseshoe Hills.

Figure 6

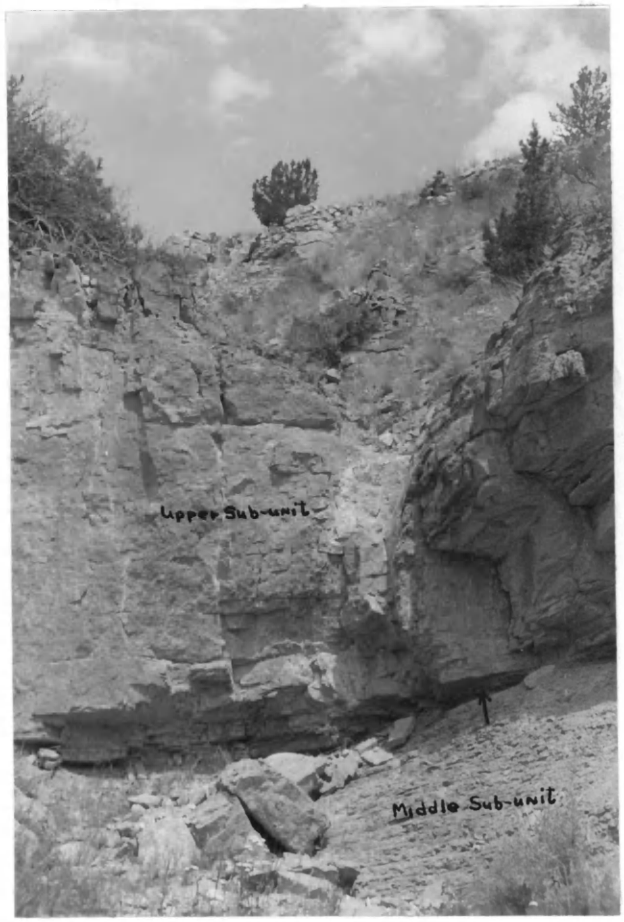


View of the lower black shale member
at Hardscrabble Peak, Bridger Range.

Figure 7

View of upper black shale member (beneath base of pick) at Hardscrabble Peak, Bridger Range.

Figure 8

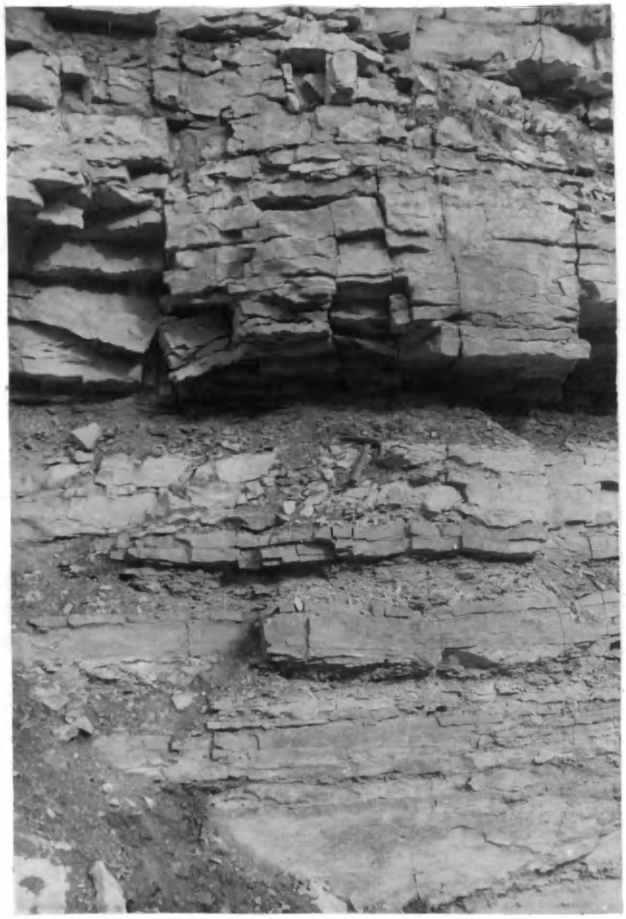


View of contact (arrow) between middle subunit and upper subunit of middle member at Milligan Canyon.

Figure 9

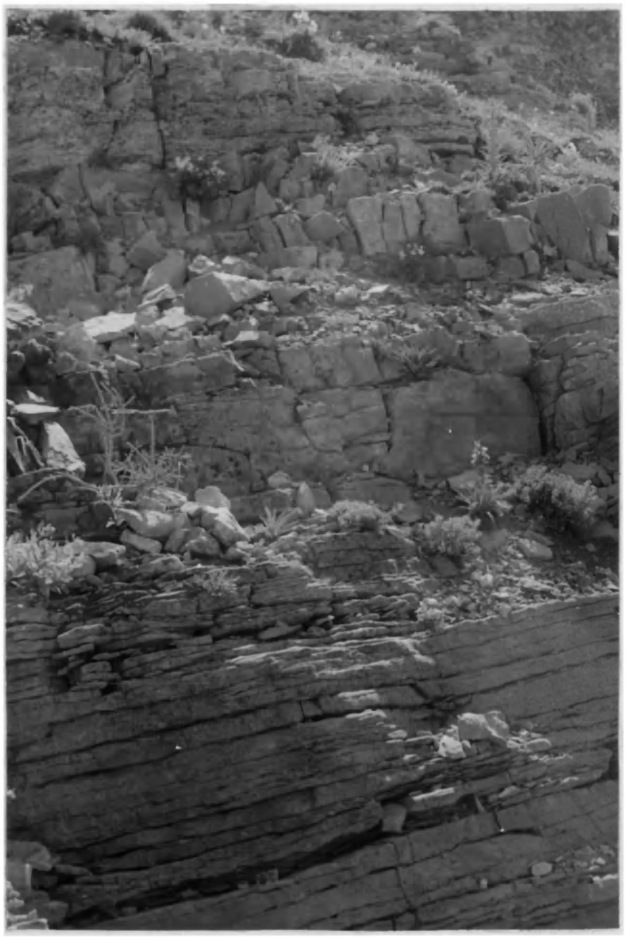
View of the contact between the Sappington middle member and the Lodgepole formation without the intervening upper black shale member at Milligan Canyon, the Sappington type locality.

Figure 11



View of the conodont and spore-bearing Little Chief Canyon member of the Lodgepole formation on Crystal Lake Road of the Big Snowy Mountains of central Montana.

Figure 10



View of the upper part of the siltstone unit that underlies the Lodgepole formation on Sheep Mountain in the Centennial Range, southwestern Montana.

Figure 12

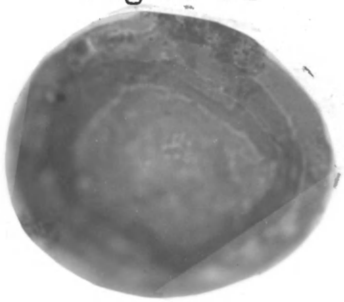


Figure 13

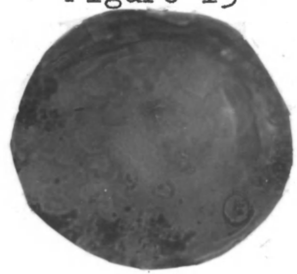


Figure 14

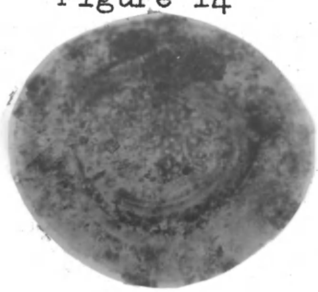


Figure 15

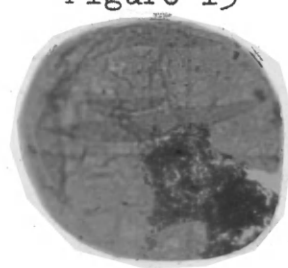


Figure 17

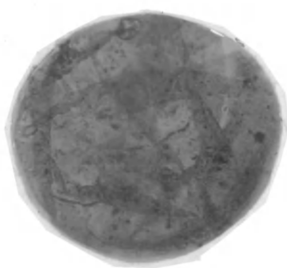
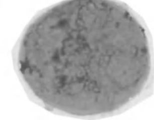


Figure 16

Figure 18



Explanation of Figures 12 to 18

(All figures X385)

Figure 12: *Tasmanites*; fairly thick spore coat, inner rounded fold parallels the circumference of spore, 250 microns (long diameter).

Figure 13: *Tasmanites*; fairly thick spore coat, punctate, slight evidence of folding of spore coat near edge of spore, 232 microns (long diameter).

Figure 14: *Tasmanites*; shows a circular-shaped split in the spore coat, 240 microns (long diameter).

Figures 15 and 17: *Tasmanites*; thin-coated forms showing many folds in spore coat. Figure 15, 192 microns (long diameter); Figure 17, 160 microns (long diameter).

Figure 16: Unassigned spore thrown slightly out-of-focus to demonstrate its punctate-reticulate ornamentation, 80 microns.

Figure 18: Unassigned spore, slightly punctate-reticulate, 96 microns.

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